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Stator in a rotating electric machine

The present invention relates to central parts of an electric rotary machine, i.e. a motor or a generator, and more precisely a step machine. Those parts to which the invention relates, are a stator arranged centrally or peripherally, and construction parts contributing to build said stator.

A machine that comprises technical features related to the present invention, is previously known from Norwegian Patent No. 174947. In this patent, see figs. 1, 2 and 3 appended hereto, is disclosed a system of "fingers" 5, 6 working as flux conductors around the stator coil or coils, and providing peripherally directed magnetic flux in external gaps 7 between such "outer finger joints/links" 15, 17 pointing in successively opposite axis-parallel directions, for interaction between these magnetic fields and magnetic fields from permanent magnets 9 on the inside of an external and concentrically arranged rotor 10. Such a motor can be named "transverse flux machine", because the magnetic flux runs substantially in a transverse direction, i.e. in an axis-parallel direction of the inside of the annular coil, then in a radial direction at the side of the coil, then substantially in an axis-parallel direction once more on the outside of the coil, and finally radially back again on the other side of the coil.

In NO 174947, the "fingers" 5, 6 are mentioned as "lamella blocks" consisting of thin sheets. These lamella blocks are in physical contact with a separate coil core 8 arranged radially inside the coil in question (not shown). However, manufacturing and mounting coil cores and lamella blocks are difficult and expensive tasks.

The present invention aims at providing a more advantageous construction of the "finger structure" in the machine stator, both technically and economically.

In accordance with a first aspect of the invention, there is therefore provided a stator element for use in a rotating electric machine that is preferably of the transverse flux type, and the stator element is characterized in that it is constructed with a pole piece, a flux-conducting section and a coil core part integral as one piece, with the flux-conducting section between the pole piece and the coil core part.

In a preferred embodiment, the stator element pole piece has an elongate shape in a direction parallel to the machine axis, with a length approximately twice the length of the coil core part in the same direction, the flux-conducting section being perpendicular to the pole piece as well as the coil core part, and being attached to an end of each respective thereof, in such a manner that both pole piece and coil core part point in the same direction.

Preferably, the coil core part has an angular span of  $360^\circ/n$  in the rotation direction,  $n$  indicating the number of peripherally juxtaposed stator elements that together can constitute a complete stator part.

10 In the preferred embodiment, the stator element is shaped from pressure forged and heat treated iron powder material.

In accordance with a second aspect of the invention, there is provided a stator part for use in a rotating electric machine that is preferably of the transverse flux type. The stator part is characterized in that it is constituted by a number  $n$  of 15 stator elements of the type indicated above, arranged in an annular structure so that  $n$  parallel pole pieces point finger-like in a direction parallel to the rotation axis of the machine and are situated radially on the outside or on the inside, while the corresponding  $n$  coil core parts are situated radially on the inside or on the outside to constitute together at least part of a coil core, and all  $n$  flux-conducting sections 20 are situated on the same axial side of the coil core.

In accordance with a third aspect of the invention, there is provided a stator part for use in a rotating electric machine that is preferably of the transverse flux type. The stator part comprises an annular structure consisting of

- a coil core ring to support an annular coil with a radial and an axial extent,  
25 - a flux-conducting area extending radially from a coil core ring edge to a radial position somewhat past the radial extent of the coil, and  
- a number  $n$  of separate pole pieces extending in an axial direction from the flux-conducting area at said radial position thereof and in a direction back across the coil.

30 In accordance with the third aspect, the stator part is characterized in that  
- the annular structure is constituted of a collection of several peripherally juxtaposed and separately manufactured stator elements, each being an integral unit having

- at least one pole piece,
- one flux-conducting section for every pole piece, all of these  $n$  sections constituting together said flux-conducting area, and
  - one coil core part, the coil core parts being situated tightly adjacent to each other and constituting together the coil core ring, and in that
    - every flux-conducting section is shaped in such a manner that there is a clear interspace between neighbouring sections all the way from the coil core part to the pole piece.

In an embodiment adapted to a machine having an external rotor, the pole pieces in the stator part are arranged radially on the outside. In an "opposite" embodiment in which the machine is of a type having an internal rotor, the pole pieces of the stator part are arranged radially on the inside.

In a preferred embodiment, the stator elements of the stator part are shaped from iron powder material that is press cast and heat treated.

In accordance with a fourth aspect of the invention, there is provided a stator for use in a rotating electric machine that is preferably of the transverse flux type. The stator comprises at least one pair of annular stator parts and at least one coil, two stator parts in a pair being arranged axially juxtaposed on the same axis and with pole pieces pointing in opposite directions and in between each other in a regular and interleaved manner, so as to form equally large, open flux gaps between all  $2n$  pole pieces, and the coil being situated in an annular space formed between the two stator parts in the pair. The stator of the fourth aspect of the invention is characterized in that the stator parts are like and of an assembled type such as stated above, the coil core parts together constituting a core for the coil, insulated from the coil by means of a substantially annular support structure for the stator part, made e.g. from a plastic material.

In an embodiment in which the machine is of the type having an external rotor, the pole pieces of the stator are arranged radially on the outside. In an "opposite" embodiment in which the machine is of the type having an internal rotor, the stator pole pieces are arranged radially on the inside.

In the following, the invention shall be illuminated further by means of a detailed description of the embodiments appearing from the appended drawings, in which

Figs. 1, 2 and 3 show elements of the prior art,

Fig. 4 shows a preferred embodiment of a stator element in accordance with the invention,

Fig. 5a shows a stator embodiment, namely assembled from stator elements of the type shown in Fig. 4,

Fig. 5b shows a cross section through the stator shown in Fig. 5a,

Fig. 6a shows an embodiment of an assembled stator part in accordance with the invention, in a plan view,

Fig. 6b shows the same part as in Fig. 6a, however part in a side view and part in cross section,

Fig. 7 shows an embodiment of a stator element for use in a machine having an internal rotor,

Figs. 8a and 8b show in a corresponding manner as Figs. 5a and 5b a stator embodiment designed for a machine having an internal rotor, and

Figs. 9a and 9b show in approximately the same manner as in Figs. 6a and 6b, an embodiment of an assembled stator part, however for use in a machine having an internal rotor.

In Fig. 1 that has also been discussed in the introduction, appears in a schematical manner a machine solution that is known from the above mentioned Norwegian Patent No. 174947. An outer rotor 10, e.g. a wheel rim or similar, has on its inside an arrangement of permanent magnets 9, not to be discussed further here. These permanent magnets 9 interact with variable magnetic fields on a stator 18 situated internally, the variable magnetic fields crossing the gaps 7 between radially outer "finger links" 15, 17 of "fingers" 5, 6 having "trunks" 14, 16, see also Figs. 2 and 3 that show "the fingers" 5 and 6 in a side view. "The fingers" 5 have a  $\Gamma$  shape, and "the fingers" 6 have a T shape. Each "finger" structure 5, 6 is preferably a stack of thin sheets, such as appearing in Fig. 1.

Radially innermost "the fingers" 5, 6 of the previously known device lie closely adjacent to a coil core 8, and in the space radially outside coil core 8 and inside "the outer finger links" 15, 17 there is a (not shown) coil, that when energized, gives rise to magnetic flux that follows "the fingers" from the coil core and crosses the gaps 7 between oppositely pointing "outer finger links" 15, 17.

In the motor embodiment appearing in NO 174947, at least two such coils are included, and therefore a T-shaped "finger part" 6 stands between two coils, extending "outer finger links" 17 out in two directions. Fig. 1 shows a structure like that, but the drawing might just as well show a simpler structure having only one coil, i.e. only with a "finger type" such as shown by reference numeral 5, i.e. reference numerals 6 and 17 can then be exchanged for reference numeral 5 and 15 in Fig. 1.

In Fig. 5a appears a structure having the same function as stator 18 in Fig. 1. This structure is assembled from smaller parts, namely such stator elements 20 as shown in Fig. 4.

The preferred embodiment of a stator element in accordance with one aspect of the invention, is shown in Fig. 4, in two orthogonal views. It appears that the stator element from the start is made to constitute, together with several similar elements, a stator part, i.e. one axial "side" of the complete structure that is necessary to close the flux circuits surrounding a coil. Therefore, element 20 has been given a shape adapted to a circular sector of angle A, wherein  $n \cdot A = 360^\circ$ , with n = the number of such elements 20 forming together a complete circle.

An upper "outer finger link" part 1 is constructed to extend across the coil, i.e. in a direction that is parallel to the machine axis. The length of part 1, which part constitutes a pole piece, is preferably twice the length of the lower/inner part 3 in the same direction, i.e.  $D \approx 2C$ . Part 3 constitutes a coil core part, i.e. it is included as a part of, and thereby forms, the actual coil core when the whole structure is assembled.

The intermediate part 2 is designated as "a flux-conducting section", and all parts 1, 2, 3 are manufactured as one integral piece 20. Preferably, such a piece is press-formed and heat treated from iron powder material.

One appreciates that a certain design is favourable, for instance the radially outer surface of the pole piece 1 is cylindrical in shape in order to be adapted to a close passage of an outside rotor, and in order to constitute part of an imagined outer cylinder surface for the stator.

When now looking at the construction in Fig. 5a, it appears that a number n, in the current case  $n=12$ , stator elements 20 are assembled into an annular structure in order to constitute a stator part, i.e. such an "axial side" of a complete stator structure that has been discussed above, and which annular structure has "outer

"finger links", i.e. pole pieces, pointing in only one direction parallel to the axis. Hence, such stator elements as shown here by reference numeral 20, belong to one stator part, while the stator elements designated 20' are stator elements "at the rear side", i.e. arranged as a juxtaposed stator part on the other side of a coil.

In Fig. 5b appears a coil 4 that is situated inside the annular space formed by two stator parts juxtaposed closely adjacent to each other, Fig. 5b showing the cross section A-A indicated in Fig. 5a. A support and insulation structure 28 is also indicated in the figure. Such a support structure can also exhibit more detail and profiling than what appears in this drawing, to take into consideration requirements that need no further mention in this description, e.g. in connection with assembling operations, attachment to further units, wiring lead-through etc. In the cross section drawing in Fig. 5b, there appears one stator element 20 that is hatched, with pole piece 1, flux-conducting section 2 and coil core part 3, and one can also see parts 2' and 3' belonging to the next stator element 20' laying therebehind, while pole piece 1' is hidden behind pole piece 1.

The elements shown now form together a fundamentally complete stator (elements not shown are spokes leading to a central hub, wiring etc.).

If the dimensions all over are sufficiently small, it will be possible to manufacture a fully integral stator part, corresponding to one of the two assembled stator parts shown in Fig. 5a, which stator parts can be remembered to consist of stator elements 20 that have been manufactured as integral respective units. However, Fig. 6a shows an embodiment that is assembled from six units, using two pole pieces per unit. A geometry corresponding to the geometry of a detail-assembled element can then be created, with an assembled annular coil core part 13 (then constituting half a coil core), a number of flux-conducting sections 12 extending radially outward, in this case twelve such sections 12, and pole pieces 11 attached thereto and pointing in one and the same direction parallel to the axis, the complete structure assembled from six units that have been individually press-formed and heat-treated as one piece during manufacture.

In Fig. 6b the same stator part is shown in a side view, partly in section, and the shape can be seen to correspond to the previously described, assembled shape shown in Figs. 5a and 5b.

In a ready assembled stator part, compare Fig. 5a, a typical gap distance will be given by the range of application of the machine. If it is desirable with high rpm's and low losses, the gap is increased, and if it is desirable with a high torque, low rpm's and a compact machine, the gap is reduced. From the start, the number of pole pieces can be chosen freely, a typical number may be 24 pieces.

Instead of press-formed and heat-treated iron powder, it is possible to manufacture the integral units from soft iron or some other material that is magnetically conducting.

In an intermediate dimension range one may also use an even more integral type than the assembled stator part 19 shown in Fig. 6a, namely a solution in which e.g. a circle quadrant comprising e.g. three pole pieces, is manufactured as an integral unit by press-forming and heat-treatment, and is assembled together with three further similar units to form a complete and annular stator part. This is shown in Fig. 9. Other division proportions than quadrant sectors may of course be equally interesting.

Preferably the stator element, the stator part and the stator in accordance with the invention are intended for use in a rotating electric machine of the transverse flux type. This is a machine of the type where the magnetic flux created from the stator coil is conducted parallel to the axis, radially, substantially parallel to the axis, and radially once more around the coil, by means of an enclosing "stator housing" such as mentioned in the introduction, and the magnetic flux interacts with magnetic fields from a rotor arranged concentrically outside or inside the stator.

One single electric generator can be constructed around one single coil 4, that is with only one annular stator part at each side and with pole pieces/"fingers" pointing toward each other and in between each other on the radial outside of the coil, and with a rotor that is driven, concentrically on the outside.

In order to manufacture an electric motor of generally the same type as in NO 174947, the set-up just mentioned, must be doubled, i.e. one needs two juxtaposed coils having corresponding, surrounding stator parts, and the outside rotor, that can be driven by means of controlled AC current in the coils, then has magnets arranged on the inside in accordance with a scheme as indicated in NO 174947. It is not necessary to go into further detail regarding such schemes in the description of the present invention.

There exists of course a possibility for a complete reversal of the structures that have been discussed in detail so far, i.e. a reversal in such a manner that the rotor is situated concentrically on the inside, while the stator is external and has its coil core farthest out, and the previously mentioned "fingers"/pole pieces situated 5 radially inside the coil. It is referred to Fig. 8a, which figure in a corresponding manner as Fig. 5a shows a "complete" stator having two juxtaposed stator parts. The difference is in this case that the pole pieces 21 are arranged radially inside, while the coil core parts 23 are situated radially on the outside. In the same manner as previously, the flux-conducting section 22 is situated between the coil core 10 part 23 and the pole piece 21, binding these parts together, i.e. the stator element is an integral unit.

The individual stator elements are shown in such a "reversed" embodiment in Fig. 7, in two orthogonal views.

Fig. 8b shows in a corresponding manner as Fig. 5b, how coil 4 lies in the 15 annular cavity formed between the two juxtaposed stator parts.

Figs. 9a and 9b can be compared to Figs. 6a and 6b, and they show, as previously mentioned, a stator part 29, in analogy with the assembled stator part 19, however in a "reversed" embodiment with a complete, annular coil core part 33 radially on the outside, pole pieces 31 radially innermost (toward a not shown rotor 20 in the centre) and a flux-conducting section 32 therebetween, however in this case consisting of four integral pieces having three pole pieces on each respective piece.

In Fig. 8a, reference numerals with an apostrophe are used regarding similar details as those shown without an apostrophe, however belonging to the juxtaposed stator part (situated behind). Reference numeral 27 refers to the gap 25 between oppositely pointing pole pieces.